RESEARCH DEPARTMENT

RECEPTION OF CRYSTAL PALACE 41·5 Mc/s AND 45·0 Mc/s CHANNELS IN SOUTH AFRICA DURING THE INCREASING PHASE OF THE SUNSPOT CYCLE

Report No. K-133

(1959/5)

THE BRITISH BROADCASTING CORPORATION
ENGINEERING DIVISION

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SUMMARY

Reception reports have been received from the Panorama, Johannesburg receiving station of the South African Broadcasting Corporation in respect of the reception there during the period 1000–1800 GMT of the Crystal Palace 41·5 Mc/s and 45·0 Mc/s frequencies, and the data are here presented. The reports have been analysed for 28 months for 41·5 Mc/s and 21 months for 45·0 Mc/s. These frequencies are near the upper frequency limit for propagation by way of the F_2 layer over a long path, even near sunspot maximum.

At the most favourable time of day and season reception of 41·5 Mc/s has occurred for up to 90% of the total time, and of 45·0 Mc/s for up to 58% of the total time. Marked seasonal variations in reception are found, resulting in a relatively large amount of reception during February–April, September–November and a relatively small amount during other months, which is in general accordance with the expected seasonal variations of MUF over the path. The mean monthly path MUF has been estimated, and, though this does not correlate well with the reception results in detail, it exhibits seasonal variations similar to those indicated by the reception results, except that during December–January the estimated MUF has a high value which is not confirmed by the results. A long period variation in reception is found which is not simply related to the increasing sunspot activity, but which may be due to a similar complex variation in the path MUF, the variations of which are determined by the magnitude and direction of variations in the two quantities f^oF_2 and M4000, with increasing sunspot activity.

1. INTRODUCTION

Since March 1956 regular reports have been received from the South African Broadcasting Corporation of reception of the Crystal Palace 41·5 Mc/s channel at their receiving station at Panorama, near Johannesburg, and since October 1956 similar reports of the reception of the 45·0 Mc/s channel have been received. It was thought that, since these frequencies are near the upper frequency limit for long-distance propagation via the ionosphere, even under conditions of high solar activity, an analysis of the reception reports might provide information as to the upper limiting frequencies for such propagation, of the variations in their propagation with season and with increasing solar activity and of their relationship to the predicted MUFs for the U.K./Johannesburg circuit. The results of this analysis form the subject of this report.

2. DATA AND METHOD OF ANALYSIS

Regular reception checks on the 41·5 Mc/s channel were started at Panorama in March 1956 and on the 45·0 Mc/s channel in October 1956. Observations were made at quarter-hourly intervals from 1000 to 1800 GMT over the greater part of the period, although additional observations have later been included. Results of the observations are given in SINPO code characters. Data are not completely continuous over the whole period (those in respect of an occasional week being missing) but they are fairly so. However, for the 45·0 Mc/s channel only, there are periods of several consecutive weeks with no data, but we are informed that, for these weeks, reception checks were made but no reception obtained. The data have been treated in accordance with this information.

The reports were analysed by taking, for each month, the number of occasions when reception was obtained on a given channel at *half-hourly* intervals from 1000 to 1800 GMT inclusive. This gave for each channel, and for each half hour during every month, the occasions when reception was obtained as a percentage of the total number of observations made (called "percentage reception"). No account was taken of the strength or quality of reception, it being merely necessary for the present purpose to determine whether or not the frequency in question was below the MUF for the circuit. During a part of the daily observation period the Crystal Palace station was not *regularly* transmitting and, accordingly, for the period 1300–1400 GMT inclusive during the months October to April, and the period 1200–1300 GMT inclusive during the months May to September, transmission was considered not to be continuous. Reports in respect of these periods were therefore discarded from the analysis.

An attempt was made to obtain MUF data for the London/Johannesburg path during the months in question from the ionospheric measurements made by stations along the transmission path, but this proved impracticable because of the absence of any stations at the most significant points, and because of uncertainty about the validity of applying data from off-path stations to the great circle path. Instead of this an estimation of the monthly median MUF for the path was made by taking the predicted monthly median MUF for the path from the D.S.I.R. charts of predicted 4000 km MUF, by the 2-control point method, and by proceeding as follows:

$$\text{Estimated monthly median MUF} = \text{predicted MUF for path} \times xy$$

$$\text{where } x = \frac{\text{Slough observed monthly median } f^{\circ}}{\text{Slough predicted monthly median } f^{\circ}}$$

$$y = \frac{\text{Slough observed monthly median M4000}}{\text{Slough predicted monthly median M4000}}$$

The observed M4000 for Slough was deduced from the observed M3000 values given for each month and time of day, and the predicted M4000 for Slough was obtained by dividing the predicted 4000 km MUF as read off from the monthly charts for the position of Slough by the predicted f° obtained from the appropriate charts in the same way.

This estimated monthly median MUF would, of course, be applicable to the circuit for 50% of the time during any month but, since the percentage of occasions

when reception was obtained was generally much less than 50%, it was thought better to compare reception with the MUF which would have been applicable for 20% of the time. If the daily MUF values at any hour are assumed to have a normal distribution it can be seen that the values which occur for 20% of the time are 10% greater than the monthly median values. The estimated monthly median MUF as obtained above was therefore increased by 10% and the result was defined as the estimated MUF for 20% of the time (MUF_{20}). For comparison with the reception data it was, however, found more convenient to use the ratio of this value to the Crystal Palace frequencies of 41·5 Mc/s and 45·0 Mc/s, and the ionospheric data are therefore given in terms of MUF_{20}/Working Frequency. It is emphasised that the method used for estimating the MUF, whilst reasonable in itself, cannot take account of known complexities in ionospheric transmission (such as mode variations, Sporadic E phenomena, etc.) and is dependent on the validity of the 2-control point method. Nevertheless, because no data on the actual MUF were obtainable from ionospheric measurements along the path, it was used as an *estimate* only.

3. DISCUSSION OF RESULTS

3.1. General

In Figs. 1 and 2 the results of the analysis of the reception reports are given, for each half-hourly interval during each month, in terms of the percentages of the total number of observations when reception was obtained at Panorama. During any given month reception of 41·5 Mc/s was always more frequent than that of 45·0 Mc/s, as would be expected. The diurnal and seasonal patterns in the reception results are, however, similar for the two frequencies.

The diurnal pattern is, in fact, not very clearly defined, owing to the break in the reception period, but there appears to be a tendency for two peaks to occur, one at 1100-1200 GMT and the other at 1500-1600 GMT. Prior to 1100 GMT and after 1600 GMT there was a distinct decrease in the amount of reception, due, no doubt, to the MUF generally rising towards, or falling from, the peak diurnal value during those periods.

There is a very distinct seasonal pattern in the reception results, which is approximately repeated in succeeding years, and is approximately the same for the two frequencies. This is such that the highest reception percentages occur during the months February-April and September-November, that there is a large decrease towards the June-July period and another decrease towards the December-January period. On a circuit running from the northern to the southern hemisphere it is at the equinoxes that the MUF would be expected to be most uniformly high over the whole circuit, and in the June-July and December-January periods the greatest difference in MUF as between one end of the circuit and the other would be expected. We will consider this in more detail later. There is evidence of a sunspot cycle effect in Fig. 1, in that, during most months, there was increased reception in 1957 and 1958 as compared with that in 1956.

3.2. Diurnal and Seasonal Variations

In order to bring out the diurnal and seasonal variations and to compare

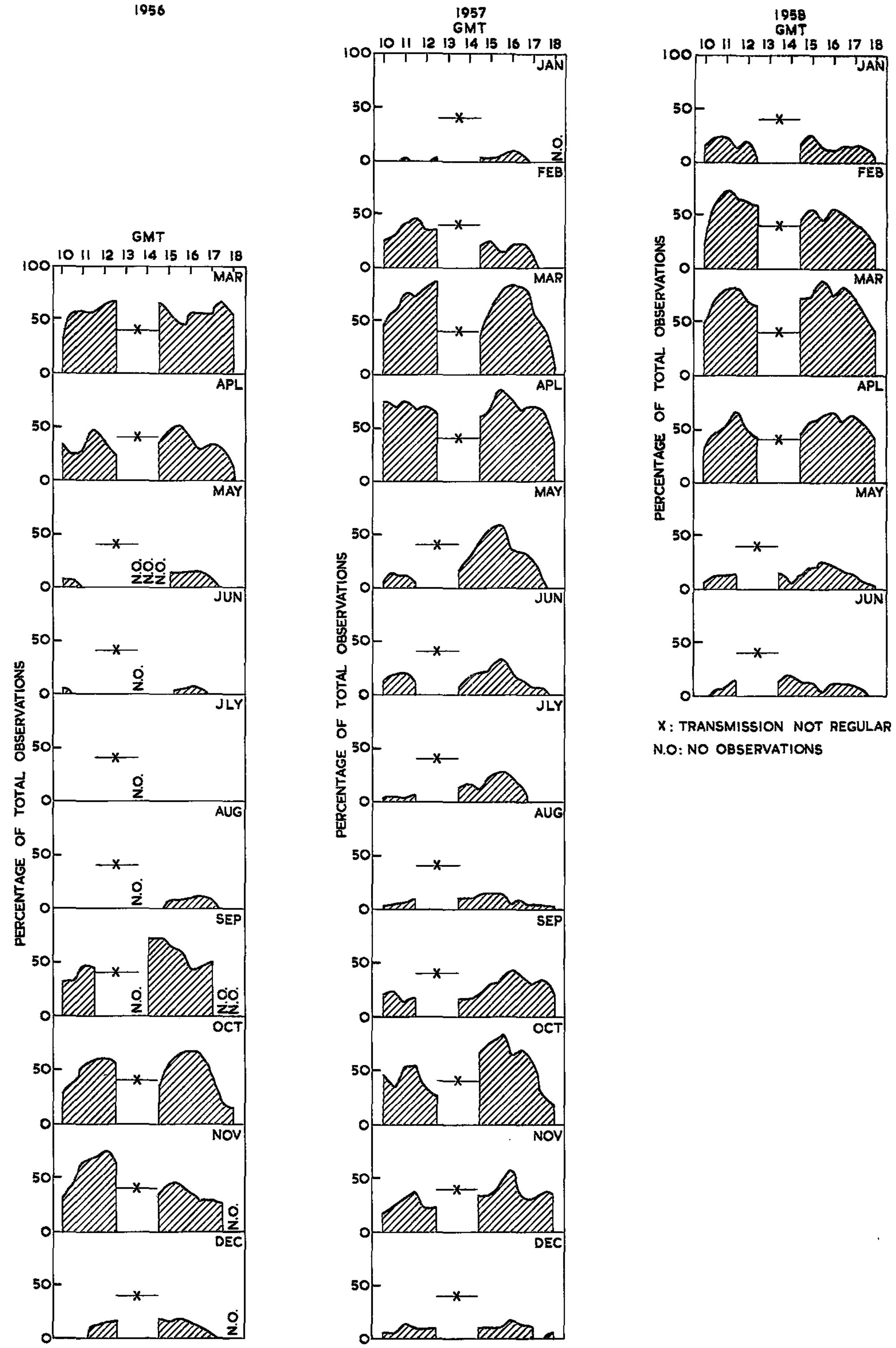

Fig. 1 - 41·5 Mc/s. Monthly percentages of number of observations during which reception obtained — half-hourly intervals — March 1956 to June 1958

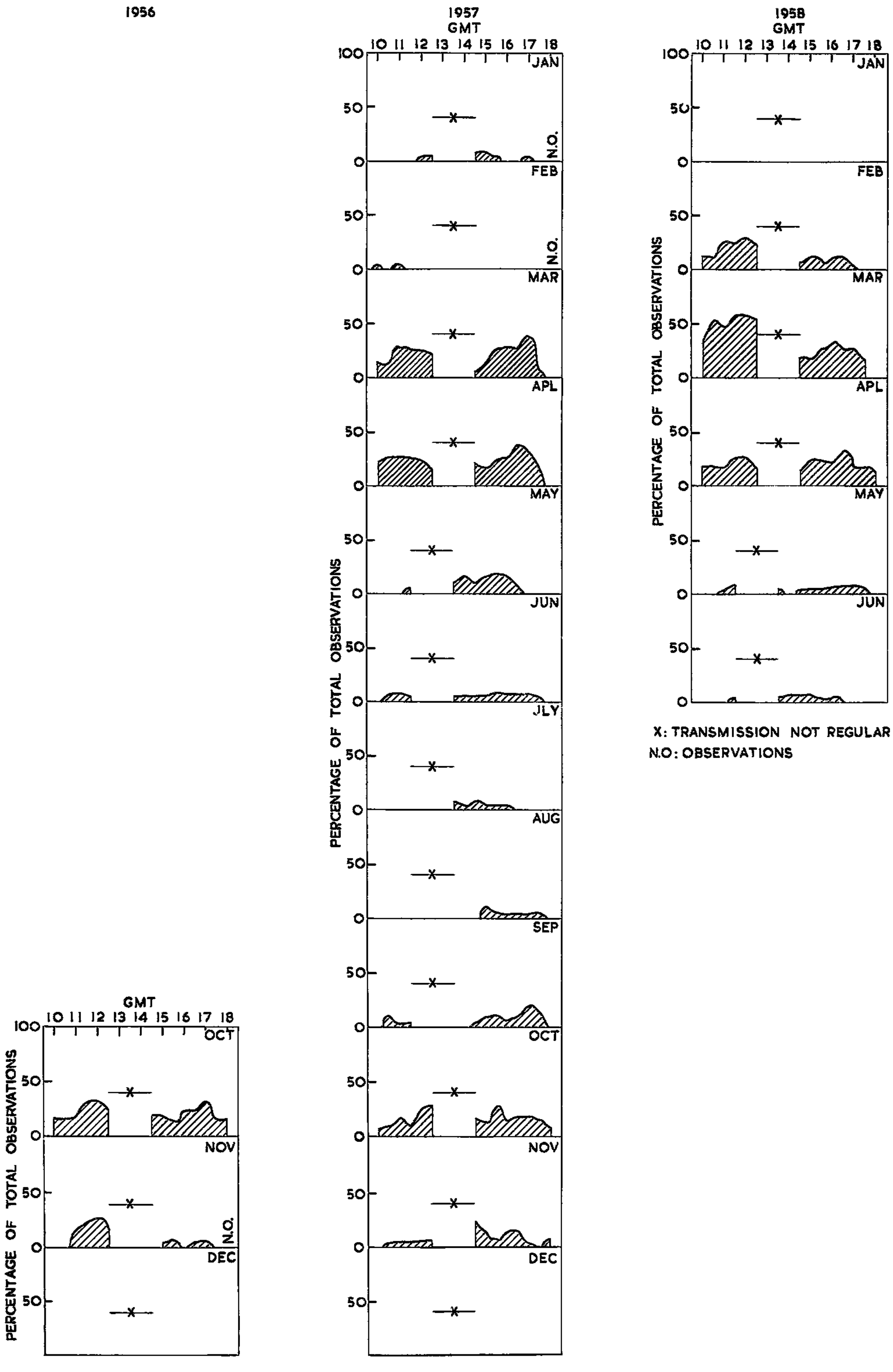

Fig. 2 - 45·0 Mc/s. Monthly percentages of number of observations during which reception obtained—half-hourly intervals—October 1956 to June 1958

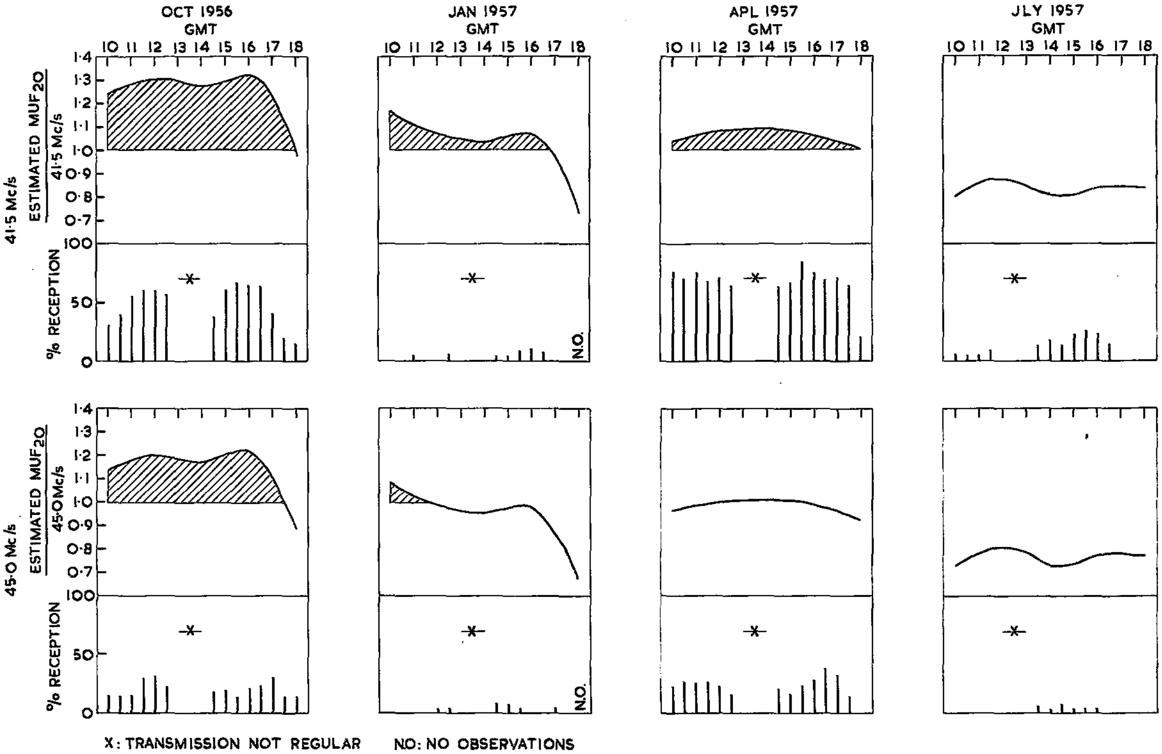

Fig. 3 - Examples of diagrams comparing percentage reception with estimated MUF for 20% of Time/Working Frequency

these with variations in the estimated MUF, diagrams like those of Fig. 3 were prepared for every month. Only eight of these diagrams are given here, as examples showing the diurnal and seasonal variations in percentage reception and in estimated MUF, and the relation between the two. They give, for each frequency, the ratio MUF_{20}/Working Frequency at the top and, at the bottom, the monthly percentage of the total observations during which reception was obtained, at each half-hourly interval. The shaded area is that when MUF_{20}/Working Frequency was greater than unity, and its size thus indicates the degree of probability of reception. Thus in October 1956 a high probability of reception was indicated and percentage reception was relatively high, whilst in July 1957 no probability of reception was indicated and the percentage reception was small. However, in April 1957 the indicated probability of reception was much smaller than in October 1956, yet the percentage reception was approximately the same, whilst in January 1957 MUF_{20}/Working Frequency was considerably higher than in July 1957, yet there was only approximately the same small percentage of reception. It is evident from these diagrams that the percentage reception will not correlate very well in detail with the estimated MUF, though there is general correspondence between the two.

As has been said there were indications of diurnal peaks in percentage reception around 1100-1200 and 1500-1600 GMT but there are but faint indications of this in the estimated MUF. There was a general decrease in percentage reception towards the end of the daily period and this is generally evident in the estimated MUF for all but the northern hemisphere midsummer months. Diurnal trends in the relation between estimated MUF and percentage reception are therefore not very obvious.

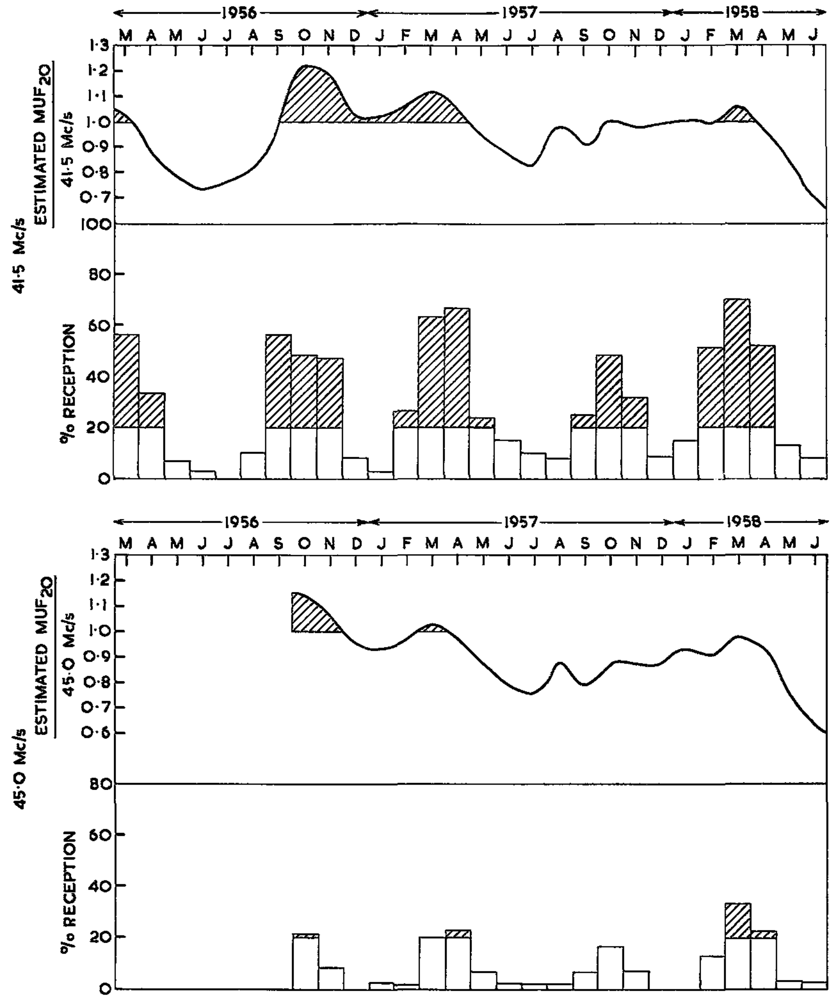

Fig. 4 - Mean monthly values of MUF_{20}/Working Frequency (curves) and monthly values of percentage reception (histograms) for the whole observational period

The seasonal variations in reception and in the estimated MUF are better shown in Fig. 4, for the two frequencies. In these diagrams the top curves were obtained by taking, for each month, the mean of the monthly value of MUF_{20}/Working Frequency for each hour in the period 1000-1800 GMT, so that the values plotted may be regarded as the monthly mean value of MUF_{20}/Working Frequency for the whole daily period. The histograms below give the monthly values of the total number of receptions for each half hour in the period 1000-1800 GMT as a percentage of the total number of observations made at those half-hours, and thus represent the monthly mean of the percentage reception. The histograms are shaded when their value exceeds 20% in order to permit comparison with the values of MUF_{20}/Working Frequency which exceed unity, and which are also shaded.

For both frequencies the seasonal variation in reception is quite distinct, there being a relatively high percentage of reception during the months February-April

and September-November, and a relatively low one during the other months, this pattern being sensibly repeated during succeeding years. Thus there is a 4-month period of low percentage reception during the northern hemisphere summer and only a 2-month period of such reception in the northern hemisphere winter, and this is accounted for by the fact that London ($51\frac{1}{2}^\circ$ N) lies in a higher latitude than does Johannesburg (26° S). Because of this a greater part of the path lies in the northern than in the southern hemisphere, and the variations in daytime MUF with the seasons are less acute at the southern than at the northern end of the path. Thus the path is more subject to control by northern hemisphere conditions than by southern hemisphere conditions. It would be expected, therefore, that during the northern hemisphere summer there would be a relatively long period of poor reception because of the low ionisation of the F_2 layer at the northern end of the path. On the other hand, during the northern hemisphere winter, when the ionisation at the northern end would be high that at the southern end would not be so low as to cause poor reception, except during a relatively short period around the solstice.

The values of MUF_{20}/Working Frequency have a tendency to be lowest during the months May-August, less low during December-January and highest during February-April and September-November and it is evident that they do, in general, correspond with the variations in reception, and thus account for these variations. However, the agreement between reception and MUF is not, in detail, good. For example the peak month for reception on both frequencies was March 1958, though MUF_{20}/Working Frequency had a lower value then than during several months of 1956/57. On the other hand during the period September-November 1957 MUF_{20}/Working Frequency was less high than during the other indicated periods for good reception, and less reception in fact occurred then. For the 41·5 Mc/s frequency MUF_{20}/41·5 Mc/s did not fall unduly low during the December-January periods yet reception decreased to values comparable with those for the northern hemisphere summer. For 45·0 Mc/s the value MUF_{20}/45·0 Mc/s seldom rose above unity and little reception above the 20% value was, in fact, obtained.

The seasonal variations in reception may, therefore, be considered to be due to the variations in F_2 ionisation over the path, according to the reasoning above, though there is only rough agreement between their values and those for the MUF, and in particular there was less good reception during December-January than would be indicated by the MUF values. The coefficient of correlation between the MUF_{20}/Working Frequency and percentage reception values was 0·64 in the case of the 28 months of reception on 41·5 Mc/s, and 0·49 in the case of the 21 months of reception on 45·0 Mc/s.

The seasonal variations in reception and their relation to the estimated MUF are further illustrated in Fig. 5, the histograms of which give, for each hour, the mean values of percentage reception of the two frequencies and of MUF_{20}/41·5 Mc/s for the whole observational period, separately for the December-January, February-April September-November, and May-August seasons. The high values for percentage reception for both frequencies during the February-April September-November season are consistent with the high values of MUF_{20}/41·5 Mc/s during that season, as are the low values for both quantities during the May-August season. But during the December-January season, when the percentage reception values were even lower than during the May-August season, the MUF_{20}/41·5 Mc/s values were almost as high as during the February-April September-November season. The reason for this discrepancy is not clear, but it may be that the estimated MUF for the season in question is much too

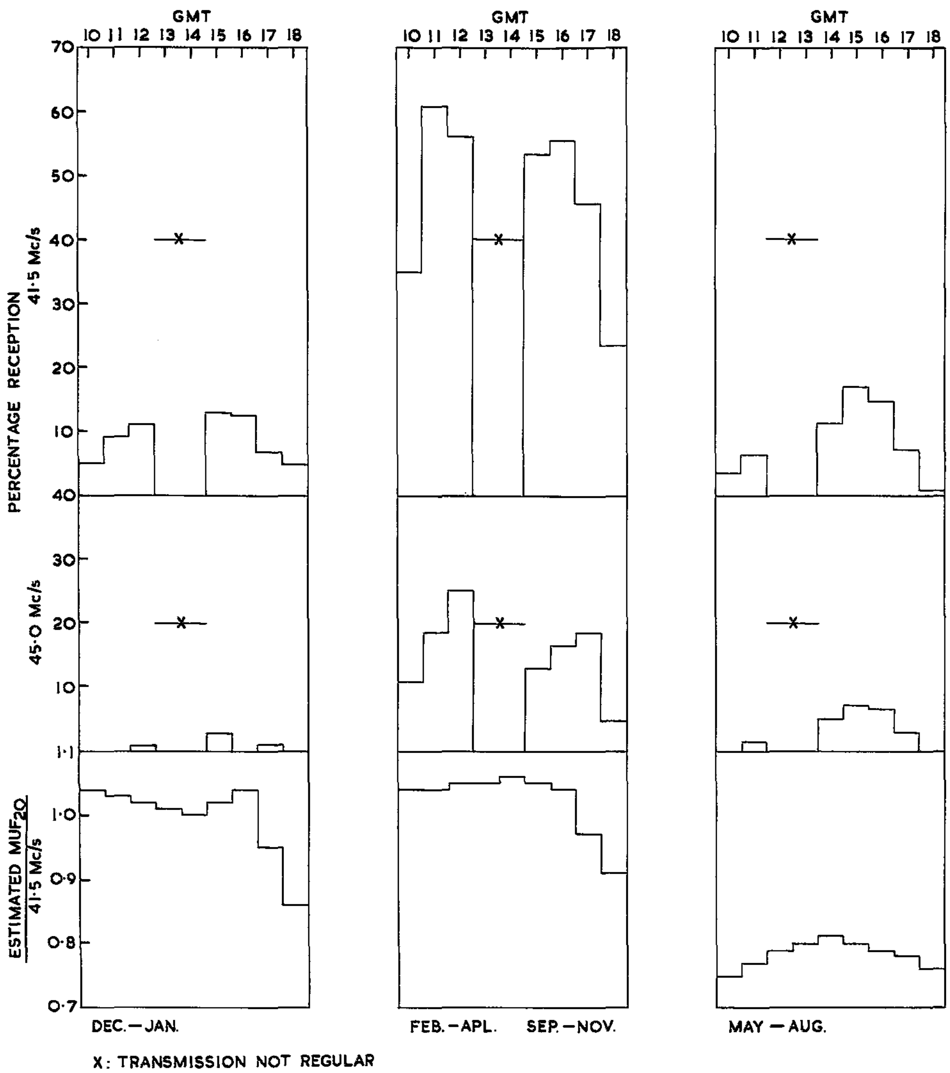

Fig. 5 - Mean values of percentage reception and of $MUF_{20}/41\cdot5$ Mc/s for each season for the whole observational period

high, in which case it is likely that the 2 control-point method of estimating the MUF is at fault, and that the real MUF for the path is controlled by other mechanisms than that assumed and possibly at different locations from those assumed.

The histograms of Fig. 6 show the mean values for each season of the total of reception obtained throughout the daily periods, and the mean values of MUF_{20}/Working Frequency for these daily periods, for the whole observational period. They again illustrate the consistency between reception and MUF values during the February-April September-November and the May-August seasons, and the discrepancy between them during the December-January season.

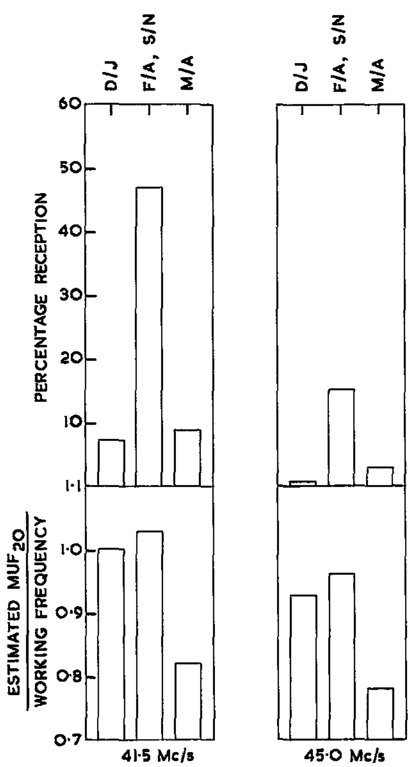

Fig. 6 - Mean values of total percentage reception and of MUF_{20}/Working Frequency for each season for whole observational period

3.3. Sunspot Cycle Variations

During the 28 months of the observational period the sunspot activity, though fluctuating from month to month, was on the whole increasing, and it would be expected, therefore, that the average level of ionisation in the F_2 layer would also be increasing and that the resulting better propagation of these high frequencies would be reflected in the reception results as an average increase in the percentage reception. In order to isolate the sunspot cycle effect it is necessary to remove the seasonal effects from the data being examined and, though other methods of doing this were tried, the method finally used was that of taking a 12-month running average of the monthly values for each set of data. In Fig. 7(a) the 12-month running average of the sunspot number is plotted for the period starting in March 1956 and ending in June 1958, the plotted values being for the epochs centred at each 12-month period. The curve shows that, apart from two small decreases, the average sunspot activity was uniformly increasing throughout the period. Curves (b) and (c) of Fig. 7 give the 12-month running averages of the monthly percentages of reception for 41·5 Mc/s and 45·0 Mc/s respectively and show that reception and sunspot activity were not simply related. In fact, instead of increasing throughout the period, the 41·5 Mc/s reception is seen to reach a peak after 6 months, then to decrease for 4 months, increase to reach another peak after another 4 months, and then to decrease again. The 45·0 Mc/s reception, though data are not available over the whole period, exhibits a trough and the second peak and subsequent decline, corresponding approximately with that for 41·5 Mc/s. The periods of increase and decline are not connected with any particular month, being different in different years, so no seasonal effects are indicated.

For comparison with the reception data the 12-month running average of the monthly mean MUF at noon GMT was taken (as being representative of the long-period MUF changes over the circuit). This was obtained by taking the observed monthly mean values of noon GMT f^oF_2 at Slough and Johannesburg, multiplying them by the observed monthly mean noon GMT M4000 for each station, taking the mean of the result each month for the two stations, and finding the 12-month running average of this MUF. The result is plotted in Fig. 7(d), and shows a peak corresponding approximately to the first reception peak, then a decline in MUF and then a further increase, which, however, in this case produces the major peak. The variation in MUF, therefore, also does not show a simple correlation with the increasing sunspot activity. The reason for this is that f^oF_2 and M4000 do not both increase smoothly with increasing sunspot number: in fact the latter shows a general decrease. When, therefore, the rate of

increase of $f^{o}F_2$ becomes low (as it did after the epoch February-March 1957) the decrease in M4000 can cause the MUF to decrease, and so account for the trough in the MUF curve. Although the correlation between curves (b) and (c) and curve (d) is not particularly good it does, however, seem probable that the long term variations in reception of these frequencies over the U.K./Johannesburg circuit are due to variations in the average MUF for the circuit, which does not necessarily increase with increasing sunspot number but is determined by the variations in both $f^{o}F_2$ and in M4000. The product of these two quantities generally increases with increasing sunspot number, but it may also decrease, due to a decrease in M4000 with increasing sunspot number.

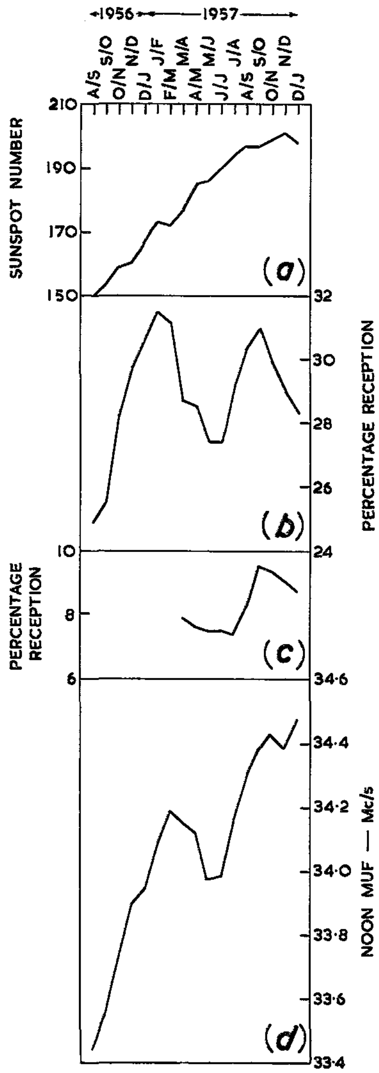

Fig. 7 - 12-month running averages of
(a) Sunspot Number
(b) Percentage reception 41·5 Mc/s
(c) Percentage reception 45·0 Mc/s
(d) Mean of Slough and Johnannesburg MUF at noon GMT

4. CONCLUSIONS

(1) Data for the reception at Panorama, South Africa, of the Crystal Palace 41·5 Mc/s frequency for 28 months and of the 45·0 Mc/s frequency for 21 months during the period 1000-1800 GMT are presented. It is shown that, at the most favourable time of day and season, such reception has occurred on 41·5 Mc/s for up to 90% of the total time and on 45·0 Mc/s for up to 58% of the total time. There are marked seasonal variations in the reception which conform, in general, to the expected variations in MUF for the path, and which result in a relatively large amount of reception during the February-April, September-November period, and a relatively small amount during the other months of the year.

(2) The estimated MUF for the path for 20% of the time does not correlate well with the reception data in detail, but, over the whole observational period the correlation is such (correlation coefficients 0·64 and 0·49 for 41·5 Mc/s and 45·0 Mc/s reception respectively) as to be able to ascribe the seasonal variations in reception to those in the MUF. The excepted months are December and January, when, for some unknown reason, the estimated MUF is high but percentage reception is low.